DOCUMENT RESUME

ED 227 835 IR 010 629

AUTHOR Hudson, Barclay; Bruno, James
TITLE Educational Forecasting Methodologies: State of the Art, Trends, and Highlights.
INSTITUTION United Nations Educational, Scientific, and Cultural Organization, Paris (France).
REPORT NO ED-80/CONF.803/INF.14
PUB DATE Nov 78
NOTE 44p.; Paper prepared for the World Future Studies Foundation, Rome, Italy.
PUB TYPE Information Analyses (070)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Classification; *Educational Planning; *Futures (of Society); Models; Multiple Regression Analysis; *Predictive Measurement; Predictor Variables; *Research Methodology; *Statistical Analysis
IDENTIFIERS *Qualitative Analysis; *Quantitative Analysis; Sensitivity Analysis; Systems Modeling; Time Series Analysis

ABSTRACT

This overview of both quantitative and qualitative methods of educational forecasting is introduced by a discussion of a general typology of forecasting methods. In each of the following sections, discussion follows the same general format: a number of basic approaches are identified (e.g. extrapolation, correlation, systems modelling), and each is described in terms of the techniques associated with its particular approach and its potential usefulness for educational planning purposes. In addition, examples of typical applications to educational planning and relevant literature references are provided for each method. Both deterministic and probabilistic (Stochastic) quantitative methods are included, with many specific techniques described including trend analysis, time series analysis, regression analysis, sensitivity analysis, econometric modelling, input/output modelling, linear programming modelling, Bayesian analysis, logit analysis, cohort analysis, and Markov chains. Qualitative methods discussed include Delphi, precursor analysis, scenario construction, morphological analysis, cross-impact analysis, and compass techniques. A brief discussion of three major trends in forecasting as applied to educational planning--increasing importance of qualitative methods, concern with the design of alternative futures, and the education of forecasters--concludes the report. A 6-page reference list is included, as well as a typology of the various methods in chart form. (LMM)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

- This document has been reproduced as received from the person or organization originating it.
  Minor changes have been made to improve reproduction quality.
- Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

ED-80/CONF.803/INF.14
PARIS, le 24 mars 1980
Original : English

ED227835

EDUCATIONAL FORECASTING METHODOLOGIES STATE OF THE ART, TRENDS AND HIGHLIGHTS

Prepared by

Barclay HUDSON
James BRUNO

University of California
Los Angeles

November 1978

Paper prepared for the World Future Studies Foundation, Rome, Italy

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

Susanne Adlung

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Note: The views expressed by the authors, the selection of facts represented and the opinions stated with regard to the facts are the responsibility of the authors and do not necessarily represent the views of Unesco.

Reproduced by permission of

UNESCO

IR010629

TABLE OF CONTENTS

I.	INTRODUCTION : A Typology of forecasting methods	1
II.	Quantitative Methodologies	4
	2.1. Deterministic Forecasting models	5
	2.1.1. Extrapolation	
	2.1.2. Multi-variable correlation techniques	7
	2.1.3. Modelling of behavioural systems	8
	2.2. Probabilistic (Stochastic) methods	10
	2.2.1. Extrapolation	10
	2.2.2. Correlation methods	11
	2.2.3. Modelling of behavioural systems	13
III	Qualitative methodologies	15
	3.1. Why qualitative methodology	15
	3.2. Extrapolation	18
	3.3. Correlation methods	20
	3.4. Modelling of behavioural systems	22
	3.5. Compass procedure	23
	3.6. Conclusions on qualitative forecasting methods	27
IV	Trends in forecasting	28
	4.1. Increasing importance of qualitative methods	28
	4.2. Concern with design of alternative futures	29
	4.3. Forecasting of education and the education of forecasters	30
V	A Final observation	30
	Footnotes	32
	References	34

I. Introduction. A Typology of Forecasting Methods

Forecasting serves a variety of functions in educational planning. Some planning takes the form of quantitative analysis--for example, long range projections of economic trends in order to adjust supplies of teachers in accordance with future demands for graduates. Other types of forecasting call for more exploratory and qualitative analysis of educational requirements--for example, constructing future scenarios of social conditions serving as a normative guide to educational policy design.

The distinction between quantitative and qualitative methodologies sets the stage for a more elaborate typology of forecasting methods. Part I of this paper deals with quantitative methods, Part II with qualitative approaches. In each section the discussion follows roughly the same format: a number of basic approaches are identified (extrapolation, correlation, systems modelling), then described in terms of particular techniques associated with each approach, and their potential usefulness for educational planning purposes (see Figure 1). In addition, each method is described with reference to examples of typical applications to educational planning, and relevant literature references.

The distinction between quantitative and qualitative methods reflects basic differences in methodology and data requirements, as well as divergent professional traditions and different personal inclinations of the analyst. In practice, however, the two approaches are complementary. Quantification and grasp of essences are complementary ways of understanding important relationships. Most forecasting problems are best solved by balanced application of objective, rigorously analysed

Figure 1. Typology of Forecasting Methods

Basic Approaches	Usefulness for educational planning	Characteristic Methodologies		
		Quantitative Methods		Qualitative Methods
		Deterministic	Probablistic	
1. EXTRAPOLATION Captures patterns as a function of time	poor, esp. for long term projections (inexpensive)	trend analysis time series analysis expontial smoothing spectral analysis simple regression	calculation of error terms sensitivity analysis	Delphi
2. CORRELATION METHODS Specification of factors affecting patterns; Considers possible breaks in current trends	fair to good	multiple regression discriminant analysis	Bayesian analysis logit analysis	precursor analysis scenario construction morphological analysis cross-impact analysis
3. MODELLING BEHAVIORAL SYSTEMS Considers substantive theory of system elements and relationships; usually includes strategic variables amenable to policy contro.	excellent (usually expensive)	econometric modelling	cohort analysis Markov chains computer simulations	genius forecasting brainstorming Compass techniques

data on the one hand, and unconstrained imagination, intuition, and expert judgment on the other.

The simultaneous application of distinct but complementary modes of thinking can be found in many fields--not only in forecasting. Advances in social sciences can often be traced to the fruitful tension between opposing styles of inquiry. For example, there is the age-old distinction between Appolonian and Dionysian modes of investigation;[1] there is William James' distinction between tender- and tough-minded philosophy (1925, p. 12); Ornstein's description of "right-brain" vs. "left-brain" thinking;[2] Heisenberg's notion of the "science of discovery" and the "science of justification," echoed in later work by Thomas Kuhn and Gerald Holton.[3] In this varied literature on dichotomies of approach to scientific investigation, there seems to be a convergence on similar conclusions. First, the tension between opposing ways of approaching a problem makes it difficult to keep the two sides in balance. It is not an easy dialectic to sustain. One approach usually ends up dominating over the other, and special attention is needed to prevent this from happening. Second, despite the antagonisms between polar ways of understanding reality, each approach needs the other, in order to compensate for its own inherent weaknesses and blindspots. The simultaneous use of different methodological perspectives can produce a more richly meaningful vision of reality than is possible with one method used alone. Third, major advances in science, ranging from chemistry to business management and social policy development, can be traced to the success of keeping opposite views simultaneously operating in the search for solutions to practical problems. It probably pays off to maintain the similar, difficult balance between quantitative and qualitative methodologies in the

field of educational forecasting.

Before turning to details of the taxonomy itself, it is briefly worth noting some alternative classification schemes suggested in the forecasting literature. A number of dichotomies have been proposed which, for various reasons, are probably less satisfactory than the quantitative/qualitative taxonomy used in this paper. The distinction between descriptive and normative forecasting, for example, is often mentioned, but in practice this demarcation proves fairly artificial. No descriptive forecast is value-neutral, because the analyst must make normative judgments (often implicit ones) about the choice of techniques used, the selection of past data points from which to extrapolate trends, the choice of exogenous variables to take into account, and even the choice of the problem itself. The "descriptive" analyst also makes value choices in considering rival propositions posed by other analysts and in testing the sensitivity of results against a range of alternative analytical assumptions.

Similarly, the forecasting literature sometimes makes a distinction between algorithms (standard techniques yielding definite solutions to a problem, such as optimal resource allocation), and heuristics, or exploratory procedures to clarify the underlying nature of problems being investigated. In practice, however, algorithms can be incorporated as part of heuristic searching--for example, in the use of computer simulation. Conversely, heuristic procedures usually play a part in selecting and tailoring algorithms to particular problems, and in making a critical interpretation of results.

One also finds a distinction being made between tactical and strategic forecasting, referring to the scale and complexity of the

social processes being investigated. But, again, the distinction is more a matter of emphasis, not a clear-cut division between techniques or modes of understanding the future. In contrast, the differences between quantitative and qualitative approaches to educational forecasting are quite pronounced, in terms of their respective methodologies, data requirements, and epistemological premises.

II. Quantitative Methodologies

A common feature of most quantitative forecasting methods is the assumption that the past is the "best" indicator of the future. Patterns of relationships holding true in the past--structured by mathematical models and statistically calibrated by empirical data from earlier time periods--are taken to hold true when projected ahead. For example, in forecasting enrollments, class achievement, future revenues or needs for graduates, basic patterns of relationships are treated as stable over time, subject to a determinable margin of error.

Forecasting methods can be classified according to the way they determine these regular patterns of relationships. (1) In the simplest case of extrapolation, the pattern is analysed purely in relationship to changes over time. There is no further consideration of why the apparent trend holds true, or what might cause it to change in the future. (2) A second category of forecasting is based on correlation methods, which seek to specify factors associated with the pattern, which in turn helps identify possible future changes in the pattern. For example, in predicting rates of graduation from college in the next decade, one could take into account such things as shifts in the job

market for college drop-outs, changing financial capacity of parents to support their children in school, and the possible effect of a military draft on the commitment of young men to pursue their students' interest in academic careers. (3) The most sophisticated type of forecast is based on modelling of behavioral systems, perhaps in the form of computer simulations, but more usually in the form of econometric systems of equations which mathematically replicate actual social processes.

Each of these three approaches will be discussed below. There is another important division among quantitative forecasting methods, however--namely, the distinction between deterministic models and probablistic (or stochastic) models (see Figure 1). Deterministic models provide a set value for the forecast, while stochastic models describe outcomes in terms of a probability distribution. Deterministic models will be dealt with first.

2.1. Deterministic Forecasting Models

2.1.1. Extrapolation. Extrapolation is the simplest forecasting technique presently in use. Simple extrapolation assumes that whatever happened in the past will continue to happen in the future provided there are no disturbances (Cetron, 1968). Extrapolation is often referred to as trend analysis and is best shown by a line represented by the equation, $y = a + bx$, where y is the independent (or outcome) variable, a is the intercept (or constant), x is the independent variable (usually in units of time) and b is the slope. Trend extrapolation has the virtue of simplicity. There is also some margin for testing the fit of different non-linear equations (log and double-log curves, exponential relationships, quadratic equations, S-curves, and so on).

Extrapolation also has important limitations. First, over the short run, the project of past averages tends to miss the extraordinary increases and decreases from year to year. Second, over the long run the projection of past averages tends to concentrate on a level of aggregation, thereby ignoring the changing nature of technological processes, facilities, and the expectations of the public. Finally, and most seriously, statistical extrapolation assumes the future will be like the past (Jeckovich, 1973). In spite of these limitations, extrapolation does serve the purpose of replicating or simulating the pattern even though it does not explain the behavior underlying the pattern. (References on the various issues in extrapolation or trend forecasting, with assessments of its limitations, can be found in Coenan, 1972; Martino, 1973; Brown, 1974; Evanco, 1976; and Frankel and Harrison, 1977.)

The following example taken from the Digest of Educational Statistics and reproduced in Brown (1974) illustrates how the graphic method is used:

> The issue addressed concerns the total number of students enrolled in full-time public elementary and secondary day schools in USA from 1959-60 to 1970-71. Starting with 1958-59 as year zero, the number of students is plotted against time from year 1 to year 12. A line is then drawn through the plotted points to fit the straight line. The line is merely extended for a few years into the future.

Brown (1974) describes several other methods of trend extrapolation in education including time series analysis, where periodic fluctuations can be considered in the extrapolation. (One application of this was to study teacher turnover. See Costa, 1972.) Another method is growth analysis, where extrapolations are considered as functions of previous levels. Examples of simple growth analysis can be found in student flow models (Bolt, 1965; Lovell, 1971) and student-teacher growth models

(Zabronski & Zurter, 1967).

Differential equations provide the basis for another kind of extrapolation. In this case it is assumed that the rate of change (not just the absolute amount of change) is proportional to time ($dR/dt = kt$). Alternatively, the rate of change may be taken as proportional to the present level of the variable itself (the future as mirror of past gains) plus some constant ($dR/dt = k_1R + k_2$). This says, for example, that improvement in reading is proportional to the reading skills already mastered. Applications of differential equation extrapolation techniques in educational forecasting include projection of standardized test scores (Bruno, 1975) or changes in racial balance (Levine, 1972).

2.1.2. Multi-variable correlation techniques. Correlational techniques in forecasting attempt to "explain" in a statistical fashion the patterns underlying forecast estimates. These statistical techniques examine specific relationships between a set of independent variables and the variable to be forecasted--i.e., the dependent variable. Once the dependent variable and the independent variables are defined and quantified, the parameters to the model are estimated using statistical procedures according to some predetermined criterion, such as the criterion of least squares for the linear additive models.

The most widely used multi-variable correlation technique is regression analysis, mathematically defined as: $y = a + b_1x_1 + b_2x_2 + \ldots + b_nx_n$. This is strictly analogous to the extrapolation equation mentioned earlier ($y = a + bx$), except that multiple regression includes more variables in explaining the outcome. The multiple linear additive model is perhaps the most widely used of all forecasting techniques because of its ease in understanding and the large amount of computer

software available (such as BIOMED, SPSS, SSP) for performing regression analysis.

Examples of the types of applications of linear regression to educational problems might be in the area of school achievement where achievement is made a function of IQ, socioeconomic status and sex (Coleman, 1966), or the impact of a part-time graduate degree on earnings (Agnello, 1976), or costs and production in university educational systems (1975). Limitations of these methods include assumptions of linearity between dependent and independent variables; problems of multicolinearity (a situation in which the variables are interrelated and overlapping making it difficult to separate out effects); and, finally, many variables in educational forecasting are difficult to measure quantitatively, such as teacher morale.

Other multiple correlation techniques include discriminant analysis and factor analysis, although their applications to forecasting have been relatively scarce. (References to use of correlation techniques in education include Adelman, 1977; and Bruno, 1976, Chapter 4.)

2.1.3. Modelling of Behavioral Systems

Models which "explain" the system of relationships leading to forecast outcomes generally come under the heading of econometric models. With these models an underlying theory must be apriori defined by the forecaster since not one but a set of equations are used to model the phenomena. Hence the principal concern is to model the pattern, explain the behaviors and validate a theory. The theory provides the mathematical structure for how the various aspects of the phenomena are interrelated. This forecasting technique currently enjoys widespread use as an effective

forecasting tool, and is recognized, especially by economists, as the most accurate and reliable of the forecasting methods. Manpower flow models and macro models of the economy are typical examples of these econometric models. Applications of these econometric or mathematical models to educational planning have been proposed by Tingerger and Bos (1965), by Emerrij (1965) for the Spanish educational system, Blum (1965) for the Turkish educational systems, William (1965) for the Greek educational system, Thonstad (1968) for the Norwegian educational system, and by Correa (1956). Two related econometric techniques--Leontief Input-Output models and mathematical programming--also have widespread use and acceptance, although their principal objective is more normative in nature.

Examples of Input-Output models in educational forecasting include allocating indirect costs (Bruno & Marcus, 1971) planning in elementary schools (Hoffenberg & Alkin, 1970), studying the relationship between educational grants and local economy (Kubursi, 1974), and the generation and forecast of teachers in California (Nordell, 1967). The classic work in this area was, of course, completed by Leontief himself (Leontief, 1951).

In linear programming models, some criterion for evaluating system effectiveness or an objective function is used. The purpose is to maximize or minimize this criterion. A matrix of equations or inequations which describes the relationships between activities and their consumption of resources is first specified, along with resource constraints. The objective function then forces a solution which best satisfies the objective while still meeting resource constraints.

Additional types of mathematical programming models, such as dynamic programming, integer programming, and non-linear programming, are basically modifications of the basic design to accommodate different assumptions about linearity, recursiveness, and continuous solutions. All basically have an objective function and a constraint set, and can also be considered as part of this forecasting classification.

Linear programming has been used to forecast a nation's rate of return to educational investments (Bowles, 1967), and GNP (Adelman, 1966), increase from alternative enrollment strategies for teacher assignment (Burie, 1974), as well as predicting student performance (Campbell, 1972), school rezoning (Heckman & Taylor, 1974), planning for vocational education (McNamara, 1968), university planning (Fox, 1975), school consolidation (Holland, 1976), and value of inputs to schooling (Holtman, 1968).

2.2. Probabilistic (Stochastic) Methods

The second important class of educational forecasting models describes the stochastic models, or models which yield a probabilistic assessment concerning some future event.* The stochastic models fall into nearly equivalent taxonomic categories to the deterministic models: extrapolation, correlation, and modelling of behavioral systems.

2.2.1. Extrapolation is the simplest stochastic forecasting technique. It is basically similar to deterministic forecasting, except that it does not stop with curve-fitting to produce a single best estimate of outcomes. Instead, it yields a probabilistic array of outcomes. These may be

---

*Bateson (1976) given an interesting derivation of the word "stochastic." It comes from the Greek word for shooting a target with a bow. A stochastic process involves a random, unpredictable component like the scatter of arrows; but only those arrows that hit the target are retained.

expressed in terms of confidence limits or envelope curves surrounding a central estimate, or they may take the form of discrete alternative estimates (for example "high," "medium," and "low" population projections), reflecting different assumptions about future levels of exogenous variables affecting the outcome. Probabilities can be assigned to each of the outcomes, for example by pooling of expert judgments through the Delphi technique (discussed below).

There are various ways of assessing probabilistic alternatives through the use of sensitivity analysis. In general, this approach measures the sensitivity of predicted outcomes to different assumptions used in the calculation. One form of sensitivity analysis, afortiori analysis, sets the boundaries of possibilities by positing an extreme case. For example, one can ask, "What if school enrollments surged twice as fast as now assumed: what could have caused that outcome? What particular combination of plausible circumstances could lead to such an event?" Another variation is contingency analysis, which identifies specific unknowns bearing on the outcome, and results in a series of predictions, each in the form of "if... then" statements. For example, "If a new scholarship fund is approved, enrollment will increase 10 percent annually; otherwise the increase will be only 7 percent."

2.2.2. Correlation methods. Models which permit the updating of forecasts with probability assessments on the basis of new information can be formulated using Bayesian analysis. This looks at the probability of outcomes resulting from combinations of prior events, which are themselves of a probabilistic nature. Estimates of these probabilities are made subjectively, but they can be revised incrementally as partial evidence comes available

to suggest modifications or reassurance about prior expectations. The inputs required by the model are prior beliefs explaining the occurrence of some event. Once this is accomplished the process can be iterative and the posterior probability can become the prior probability for the next forecast.

Applications of Bayesian analysis to educational forecasting include forecasting issues in standardized testing (Bruno & Shuford, 1978; Doscher, 1978), applications of assignment to special education programs (Ferguson, 1976) and modeling graduate admission policies (Duff & Lynch, 1976). A general discussion of the use of Bayesian analysis in education can be found in Tanner (1972) and Morgan (1968).

The principal concerns of these types of forecasting models is the use of subjective or prior probabilities, hence it is very similar to group opinion models which permit the use of qualitative as well as quantitative information for the forecast. The individual is then free to revise prior probability estimates based upon new information.

Another important stochastic methodology which is now gaining recognition by forecasters is logit analysis. This type of procedure incorporates the "behavior" explaining value of deterministic correlational models with probabilistic assessment concerning the occurrence of some future event. Basically, a logistics function defines the linear additive relationship between each independent variable and the dependent variable, expressed in probabilities. In addition, the change of probability in response to unit changes in the independent variables can also be found, somewhat in the fashion of sensitivity analysis, mentioned earlier. Applications of logit analysis to educational forecasting include the forecast of teacher militancy (Bruno & Nelkin, 1972) and forecasts of retention of army personnel

in the military (McCall and Wallace, 1967), as well as studying enrollments in elementary education (Evanco, 1976).

2.2.3. Modelling of behavioral systems. A common stochastic forecasting technique is Monte Carlo, usually in the form of a simulation. In these models, similar to econometric deterministic models, a set of equations is used to model the system. Important parameters in the model, however, are not fixed but are drawn at random from a prespecified probability distribution. The process is repeated until a steady state is reached. With the availability of large capacity computers, the value of this technique to educational forecasts should be excellent (Bruno, 1974). Its purpose, similar to econometric models, is to model the pattern, explain the behavior, and verify a theory. It has been used to forecast demand for substitute teachers (Bruno, 1970), project enrollments (Guffin & Schmitt, 1966), and junior college administration (Gold, 1966).

Another, and more widely used method of stochastic forecasting is cohort analysis, where groups of individuals are studied as a whole and survival rates noted. Examples of applications of cohort analysis are in the areas of teacher survival (Charters, 1970), school performance (Legare, 1972), and school administration (Brown, 1972). Cohort analysis is also used extensively in demographic projections, which serve as the basis for estimates of future primary school enrollments (Barclay, 1960; Unesco, 1966).

Closely related to this is the use of Markov chains. Here, information is gathered concerning the probability of being in one of a group of mutually exclusive, collectively exhaustive states. A probabilistic estimate of the transition between these states is then found. Once these two factors--an initial probability state vector and a transition matrix--are known, then the probability of being in some state at some future time

period can be calculated. In essence, Markovian process views a system "as proceeding from a present into a future stage in which one of n possible outcomes or states E_1, will be attained with a fixed probability" (Horowitz, 1970). If the probability of E_1 is independent of all previous states, it represents a zero-order Markov process. If it is dependent on one of the previous states it is a first-order Markov process, and so on.

Educational forecasting problems such as school enrollment projections (Youda, 1972; Mohrenweiser, 1969) and student flow problems in universities are based upon this method of forecasting (McNamara, 1974; Reisman & Taft, 1969). The Markov model also has wide application in sociology for studying welfare (Boskin & Nold, 1975) and social mobility (McFarland, 1970). In addition, this versatile forecasting technique has been used for studying problems in personnel administration (Vroom and MacCummer, 1968), learning theory (Reiger, 1968), organizational growth (Yuji & Simon, 1964), income distribution (Smith, 1961), career guidance (Nafziger, 1973), and educational planning (Johnstone & Philip, 1973).

Markov chains, cohort analysis and computer simulation techniques all base themselves on mathematical models (or systems of equations) that replicate the behavior of social groups or systems. Like econometric modelling, the relationships of inputs to outputs (or transitions from one state to another) can be empirically calculated, but also revised to conform to policy or other exogenous factors.

Unlike econometric modelling, however, these stochastic techniques make more allowance for the diversity of human nature. Probabilistic modelling takes into account the fact that, while people's behavior in the aggregate can be modelled with a fair degree of confidence, their individual behavior ranges widely. Particularly in the field of educational planning,

forecasters need to keep this variability clearly in view. Educational theory--and classroom practice--tells us how important it is to teach with individual differences in mind, and not just the "typical" student. Probabilistic models help the forecaster do the same.

III. Qualitative Methodologies

As summarized earlier in Figure 1, qualitative methods can be roughly divided into the same three main approaches as quantitative ones: (1) extrapolation, (2) correlation (explicit linking of outcomes to associated factors), and (3) modelling of systems, based on substantive theory of behavioral relationships.

3.1. Why qualitative methodology

Qualitative serve quantitative analysis in several ways. (1) First, it is often used to generate data, where these are not available, or too expensive to collect, or when they need to be based on pooling of subjective judgments. (2) Second, qualitative analysis helps to validate the assumptions underlying methods and models used in quantitative analysis. (3) Third, qualitative methods are often needed to take the practical step from numerical analysis to implications for policy design. Identification of new program options rarely comes directly from quantitative analysis, but from inventive conceptual exploration before and after the stage of numberical calculations. (See Toffler, 1972, pp. 154-549.)

(4) Fourth, qualitative analysis is needed to shape definition of goals, prior to quantitative analysis. One needs to start with a specification of objectives, or at least with identified problems and solutions that make specific aspects and techniques of quantitative forecasts "relevant." Particularly in the case of educational planning, intellectual, political, social, religious/ethical, and ecological factors are constantly

impinging upon the environment of educational institutions (Clark, 1969); hence forecasting in education has to be placed in the context of the country and its value systems, whether of a political or social nature (Beck, 1974). Quantitative methods tend to begin with the present and work toward understanding of the future; goal-directed analysis, however, begins with the future and works back toward the present, and is primarily concerned with the selection of desirable outcomes which will guide planning and implementation efforts.

(5) Fifth, qualitative methods encourage more imaginative modes of thinking about the future than usually permitted within a quantitative frame of reference. As pointed out earlier, quantitative methods start with the assumption of continuity between the past and the future. This posits that the same variables which were driving events in the past will continue to control them in future. Yet the very meaning of "social development" revolves around the notion of change in the structure and quality of social processes. As Arthur C. Clarke has pointed out, quantitative-based forecasts have failed less from errors of calculation than from "failures of imagination" in structuring analytical models and "failures of nerve" in interpreting their results (Clarke, cited in Toffler, 1972, p. 134). Qualitative methods help give these added dimensions to analysis, by going beyond the cautious mentality of statistical "number-crunching."

(6) Finally, qualitative analysis helps specify the environment which may affect forecast outcomes. Quantitative methods operate within a "closed" system of variables (independent and dependent, exogenous and endogenous, causal and outcome). Good forecasts, however, usually consider a range of environmental contingencies. Instead of predicting that "X will happen," a good forecast will generally propose a series of "If..then"

statements. For example, "Enrollment will increase rapidly, other things being equal; but it will not outstrip teacher supplies if immigration slows down. In the worst case (continued high immigration and enrollment increases), the teacher supply gap requires implementation of contingency Plan B to upgrade apprentice teachers."

This last point reveals some special features of qualitative analysis. Accuracy is not always the best measure of such forecasts. Nor is consensus. Nor is the objectivity of the procedure. On the contrary, good qualitative forecasting often involves a confrontation of rival hypotheses about the future, none of them objectively "true" nor necessarily consistent with the past, nor even likely to come true. For example, a forecast might demonstrate simply the possibility that an unlikely combination of events might produce a disasterous result. This would be worth the attention of policy makers even if it represented a minority opinion and could not be demonstrated by hard data. Qualitative methods can be used to support speculative forecasting of this type, whose basic role is to get people to examine the assumptions built into the model. These help illuminate the nature of social processes and the scope of policy options needed to deal with long range outcomes beyond the horizon of normal decision-making. The world dynamics models sponsored by the Club of Rome are a good case in point. (Meadows and Meadows, 1971; Mesavoic and Pestel, 1974.)

Although different from numerical analysis in the kind of data and technical methods used, qualitative analysis nevertheless addresses the same types of forecasting purposes as quantitative methodologies. Conceptually, the same three classes of forecasting method apply--extrapolation, correlation, and modelling.

3.2. Extrapolation. In the absense of more systematic methods, planners tend to employ crude versions of extrapolation forecasts: "Is X growing?" 'X might be a problem, or a magnitude, like size of social demand for education, or a flow, such as rate of success in passing a level of achievement); or, "Is the rate of growth changing?" or "Are we looking at a typical S-shaped growth curve, likely to flatten out at a new plateau?"

Often, it is enough to make crude estimates of long-range tendencies and general magnitudes. This may be sufficient to set general policies in motion, allowing fine-grain adjustments to be worked out from year to year. This requires little or no numerical calculation, but instead draws on systematic pooling of judgment about whether a general pattern of change or stability will tend to materialize over the long run.

Delphi is one of the best known techniques for this purpose, and its applications have been widespread (see Bruno, 1976; Weatherman and Swensen, 197'; Hudson, 1978, for applications to educational policy and planning) Delphi is a technique which attempts to make effective use of informed intuitive judgment. It is based on the premise that projections into the future which affect public policy decisions are largely based on the personal expectations of individuals rather than on predictions derived from well-established theory (Helmer, 1968). Delphi is a means of securing a survey of opinion from a group of experts without bringing them face to face, but using a series of questionnaires. Feedback from each questionnaire is jointly discussed, to assist the experts in making their revised (but still independent) response to the next round of questions. Delphi usually asks questions along the lines of whether a projected outcome is desirable, whether it is feasible, how important it is in relation to current policy decisions, and how soon the outcome is likely to come about.

Delphi has advantages in that it allows for "reasoned self-aware opinions;" it provides feedback that is more accurate than that gained in face-to-face discussion; and "it creates a well-defined process" that is replicable. It also allows both quantitative and qualitative data to be taken into account in making judgmental forecasts. On the other hand, Delphi may lead to "self-fulfilling prophecies;" the form of the questions may in themselves influence the opinions; and most importantly, it is often difficult to assess "who are the real experts" to invite as participants in a Delphi exercise (Lanford, 1972). (See also Linstone and Turoff, 1975.)

A practical application of Delphi might be the distribution of a series of questionnaires to identified experts seeking their predictions of the effects of racial integration on a specific aspect of public education. Of course Delphi is limited by the knowledge and expertise of those surveyed and the ability of the reasercher to interpret the responses. An excellent discussion of the limitations and future of the Delphi technique can be found in Mandanis (1969).

The uses of Delphi lie not only in the areas of forecasting as described above, but can also be used as a strategy probe concerning which plan or course of action should be taken (Klein & Alkin, 1971). The most widespread use of Delphi is in preference probes--what <u>should be</u> instead of what <u>will be</u> (Adelson, 1967).

Concluding this section on extrapolation, it is worth noting that qualitative analysis, without deep involvement in empirical data, can concentrate attention on the qualitative nature of trends being examined. Different types of growth curves may be considered (S-shaped, logistic, or Verhulst); or cyles (some too irregular to fit mathematical patterns, but discernible by visual plotting); or benchmark patterns involving association

between characteristic sequences of events (Young, 1968, p. 20). Most of these patterns can be described or verified mathematically, but identification of historical patterns themselves is a matter of qualitative rather than quantitative analysis.

3.3. Correlation methods. This class of methodology deals with interrelationships among a variety of factors having a joint effect on future outcomes. Patterns are explained not just as a function of passing time (as in trend extrapolation) but within a system of correlated relationships. Specific methods include precursor analysis, surprise-free scenarios, conjoint analysis, and cross-impact analysis.

Precursor analysis looks at sequences of events, attempting to discern early warning signs for future events. This is analogous to the use of "leading indicators" in business analysis. In education, precursor analysis has its main use in anticipating problems: teachers can be trained to watch for early signs of learning disabilities in particular students; district supervisors can look for schools in trouble, for example by rising incidence of vandalism; phone companies, public utility agencies and moving companies can identify district-wide rates of change in population shifts.

Scenario construction is essentially a narrative of developments leading to a future state of affairs--a writing of future history. Scenarios are often written in the past tense, looking retrospectively at the present from a presumed vantage point of an imagined future situation (Barnes, 1978; Harmon, 1976). This might be a crisis to be avoided, or it might be a relatively utopian solution to present problems which can only be solved by long-range policies. Such policies require powerful images to gain a commitment to appropriate action in the present. Radical educational experiments have often had their source in this kind of utopian projection

(examples are Summerhill and Communitas). On a larger scale, national educational policies have sometimes been designed in response to specific events or crises, which are then portrayed as warnings of need for better national preparedness in the training of the next generation. For example, the American Civil War during the 1860's gave a major impetus to the Land Grant College system (Hudson, 1973); World War II created the close link between universities, private business and government in creation of the research and development industry (Kerr, 1964); and the launching of Sputnik (1957) had a major effect on American education through the National Defense Education Acts of the 1960s. All of these policies were developed on the basis of making projections from specific events to scenarios of future social needs, and the drawing out of implications for educational policy priorities.

The approach just described begins with the assumption of a basic discontinuity between the present and future--through leaps of imagination, major new policy departures, the design of new institutions, the problems and opportunities presented by crises. In contrast, another form of scenario building--known as "surprise-free projections"--begins with the premise of basic continuity in social processes. It examines current trends in perhaps a dozen major sectors--demographic, political, material and energy resource supplies, political climate, national morale, economic growth and stability, social values relating to life-styles, and so on. Looking at trend and interactions among these processes, a single "most probable" scenario is developed. Paradoxically however, it is known that the "most probable" scenario is unlikely ever to come about, because history does not follow "surprise-free" paths. Therefore the forecaster looks at scenario variations, in which individual sectors, or clusters of sectors

depart from current projected trends. This creates alternative future scenarios, branching out like the limbs of a tree from the central trunk. The choice of departures is as much an art as a science, but certain basic principles of scearnio-building have been evolved on the basis of studying the outcomes of past attempts at long-range forecasting. For example, in the area of technology forecasting, both "experts" and the general public tend to be too conservative in predicting the potential for major breakthroughs in the long run (more than 25 years), but over-optimistic about short-range developments. (See, for example, Jantsch, 1967; Linstone and Turoff, 1975 ; Stanford Research Institute, 1970.)

3.4. Modelling of Behavioral Systems

In long range forecasting, much depends on interactions among events correlated in time. Where strong interactions occur, it is important to know whether they are mutually reinforcing and in what direction. For example, improved quality of schools in a local district among geographically mobile populations may attract upwardly mobile, achievement-oriented classes of people. Their children, in turn, will be good learners. This will enable local schools to attract and hold good teachers, which increases the quality of the school and the attractiveness of the neighborhood. The same cyclical process can also work in reverse, explaining the difficulty of providing equal quality education among different school districts, and the tendency--even within public education--for sharp differences of social class to arise between one school district and the next.

Good forecasts of such trends (and good design of relevant policy) depends on isolating social processes or systems characterized by strong internal linkages, and weak external relationships to everything else.

This allows the analyst to consider a finite set of variables independent of other factors that are irrelevant (or at least less relevant) to solving the problem at hand. There are various techniques for isolating such systems, including morphological modelling, cross-impact matrices, and conjoint analysis. In cross-impact matrices, events are arranged in a matrix with a set of probabilities which will enhance or retard the development of outcome (Hudspeth, 1974; Gordon and Hayward, 1968). In conjoint analysis, two or more policy alternatives are ranked on two or more attributes. Using multidimensional scaling procedures, the rank order data is replicated along an interval scale (Wind & Spitz, 1976; Guen & Rao, 1971). In morphological modelling, social systems are broken down into independent sub-systems, and portrayed in terms of a diagram of policy design possibilities, logically arrayed into sub-classes (WSF, 1977, Chapter VIII).

3.5. Compass procedure

Another forecasting method based on qualitative modelling of social systems is the compass procedure. Compass is somewhat similar to Delphi in relying on pooling of judgment and available knowledge to assess outcomes that cannot be determined purely on the basis of objective evidence. Like Delphi, it involves debate on selected questions, focussing on strategic policy variables, and can be used to design and evaluate policy options.

It is different from Delphi in several important respects, however. It does not use a questionnaire, and needs little preparatory work. Instead, responses to questions are recorded on a single graphic wall display. Major attention is given to points of uncertainty and disagreement rather than the more obvious areas of consensus. Points of contention are sorted out according to whether the issues can be resolved by factual verification, whether they revolve around differences in social and personal values, or whether they involve problematic linkages of cause and effect which require more

focused and long-term investigation.

Discussion begins with a single "catalyst" question--for example, "Will enrollment rates increase, rather than levelling off over the next two decades?" Or, "Are the consequences of lower enrollments chiefly beneficial?" Or, "Have we been successful in past attempts to accommodate unexpected surges of enrollment?" Or, "Should we adopt large-scale implementation of an experimental program to create para-professional teachers, in response to future enrollment fluctuations?"

Answers are sought in the form of a dialectic: "Yes, this will happen (or should happen, or can happen) because ...," or "No, because...." The behavioral system underlying projected outcomes is then constructed out of these "becauses." The product of the exercise is not a single snapshot of a predicted duture, but a series of possibilities and decision-points that will come to play along branching paths between the present and some future state.

Compass starts by simply laying out a "reasonable" image of some future outcome, with a concise list of underlying assumptions--the "becauses" that people give in explaining their position. Once these assumptions are openly stated, each is critically examined, usually in the form of counter-assumptions generated by earlier contradictory opinions. Once these are listed, attention narrows on a sub-set of "critical" assumptions--those with equally plausible rival arguments on each side; those involving one or more special interest groups having major stakes in the outcome; those having direct bearing on policy design; and those which can be resolved by rapid and inexpensive methods of policy research.

Compass usually operates in two stages. The first (described above) consists of a brief workshop, whose findings are presented in a concise

interim report for critical feedback--the entire process spanning about 24 hours. The second stage is optional, consisting of follow-up investigation into the tentative conclusions and key issues raised in the first report. This can range from a day to two weeks, and can include preparation of a longer term research agenda using more conventional methods of decision analysis and evaluation research. The product of each stage includes a tentative but concrete set of policy conclusions, which can be accepted, modified, rejected, or suspended pending additional feedback and investigation. In either case, however, there is a tangible line of action to work with, serving as a point of departure for concrete reactions, and a basis for focussed research on concrete options identified. In practice, the final policy choice is often a mix between two or more clearly defined alternatives. Strategies rarely come from contemplation of abstract objectives or from wholesale adaptation of an initial proposal, but from starting with concrete options, and mixing their respective elements in ways best suited to local conditions.

Compass also provides an agenda for high-payoff research, making explicit the remaining areas of uncertainty and disagreement that bear most directly on subsequent policy choices.

Compass is designed to look beyond official policy objectives to also consider indirect and intangible side-effects, including cultural, aesthetic and psychological factors that, in practice, have important effects on public and political support for a policy decision, or influence them against it. In contrast, most other methods of policy analysis and forecasting focus more narrowly on a few dimensions of outcome that are objectively measurable, politically safe to articulate (therefore highly aggregative and vague about definitions of "the public interest"), and relatively

unspecific about unique or localized historical processes which may sway the course of events toward one type of outcome or another.

In seeking to articulate this broad and historically specific "landscape" of forecasting elements, the Compass procedure usually involves participation by a cross-section of concerned parties--decision-makers and funding agencies, bureaucrats and field supervisors, teachers and parents--and even students, who after all have an important perspective of their own on alternative educational futures. Participants are chosen to provide diverse perspectives on social processes and policies affecting the future, not a consensus of expert opinion alone. (Delphi, in contrast, focuses more narrowly on questions that reflect specialized expertise, with answers that will ultimately be vindicated as "right" or "wrong." Consequently, there is a built-in pressure for respondents to conform to the authority of majority opinion or to the judgment of a respected individual.) Delphi devotes much attention to ways of avoiding this "band-wagon" effect, chiefly by the use of questionnaires to preserve the anonymity of respondents. The construction of questionnaires--usually in several iterations--collection of responses and collation of results is quite burdensome. Compass avoids this by asking a different kind of question: not what do experts know, but what alternative possibilities emerge from a variety of people having quite different perspectives on the way "the system" operates. Experts are not under pressure to make a "right" or "wrong" forecast, but to consider a broad set of possibilities, each with its own array of underlying assumptions and counter-assumptions. Without the pressure to conform, questionnaires become unnecessary. By eliminating questionnaires, the structure of questions and answers is less constrained by apriori categories for describing the range and meaning of outcomes being forecast. (For a more extended

discussion of the Compass approach as it applies to educational forecasting, see Hudson, 1978.)

3.6. Conclusions on qualitative forecasting methods

To conclude this section on qualitative forecasting methods, there are clear advantages in going beyond pure extrapolation in order to examine substantive factors influencing outcomes, particularly in making long-term projections. In most cases, the methodology consists of systematic laying out of the parts, in order to compile evidence and judgment about the strength and directions of relationships.

In some cases, however, qualitative forecasting is based on more wholistic, intuitive leaps. This is somewhat in the nature of science fiction, but it can be based on a solid understanding of historical processes, human nature, and specific problems being addressed. One taxonomy of futures research (Gordon, 1972, pp. 164-189) includes "genius forecasting"--the use of intuition inspiration, insight and luck, as represented in such thinkers as Francis Bacon, H. G. Wells and Arthur C. Clarke. It can probably be said that good educational planning should always incorporate an element of "genius" in the sense that insight and inspiration are always useful; and forecasts always rest on a little luck. In most cases, however, when genius is applied to educational planning, it is usually directed to short-range problem-solving. Some educators, like Dewey and Montessori, have demonstrated outstanding capacities for scenario building, relating the world of the child, the family, and the school to a larger vision of social institutions and purposes. Yet even in these cases, attention has been mainly focused on relationships in the present rather than anticipation of the future.

Many of the talents and methods needed for qualitative forecasting can be found already applied to other, more mundane and short-term forms of

problem-solving. Unfortunately Western culture has not promoted much thinking about the long-range future. Policy science is presently dominated by economic thinking, which has the peculiar quirk of discounting the future in accordance with the going interest rate for public sector capital. Our education systems themselves do not encourage much thinking about the future. Schools teach history, but not future histories; they teach philosophy, but usually derived from ages long past; social science, but rarely in the context of projecting reality beyond the present; art, but almost never as a way of creating a clearer image of alternative futures.

In sum, educational forecasting is not simply a problem of developing specialized methods, but of extending the application of existing techniques to future realities. Forecasting stems from future-oriented attitudes, not just a particular set of techniques.

IV Trends in Forecasting

This concluding section will consider three major trends in forecasting as applied to the field of educational planning.

4.1. Increasing importance of qualitative methods. Educational planning has evolved rapidly since the 1960s, moving beyond its traditional concern with quantitative analysis. Conventional educational planning has focussed on three types of problems: manpower analysis, estimation of social demand; and cost-effectiveness analysis. A review of recent literature, however, shows that the field has become far more diversely concerned with problems that call for more qualitative forms of analysis: life-long education, integration of planning with local conditions, relation of education to work in domains of competence outside technical skills, and application of planning to address long-range social development and ideological objectives

such as equity (see Hudson, 1977, esp. pp. 6ff). Most of these issues involve forecasting, but not usually of a strictly quantitative nature.

4.2. Concern with design of alternative futures. Another trend seems to be in the direction of forecasting that goes beyond "most likely" outcomes in order to engage in constructive policy design. This involves attitudes, skills and techniques of social inventiveness. As Toffler points out (1972, pp. 4, 154-159) future studies are becoming less dogmatic about what "will" happen and more open to description of fluid, malleable futures, subject to policy guidance and control. Alternatives futures are being explored not only with more sophisticated techniques, but through more fundamental attention to issues of epistemology. Social scientists are asking themselves--What can or cannot be known?--What are the grounds for understanding events in the future, as distinct from scientific investigation of things that have already left their mark for empirical study? If the future is created to some degree by expectations and self-fulfilling prophesies, who are the belief-makers? For example, in constructing the reality of future educational systems, whose reality are we taking into account? What about the reality of people who have never been well served by education--the poor, the minorities, the creative nonconformists, the people who shun the competitive ethic in an educational system which can only create winners by also creating relative losers?

Issues such as these can be raised especially vividly in future studies, which stand back from the present to consider "how the system works" in a more fundamental way than is possible when dealing with short-term problems. Forecasting is increasingly moving beyond simple extrapolation of trends to probe the structural nature of behavior in social systems. At this level of understanding, the forecaster can begin to ask--not just why

things presently happen the way they do, but what are the alternatives?

4.3. Forecasting of education, and the education of forecasters. A third major trend in this field is that skills, attitudes and techniques of forecasting are becoming more widespread--more part of everyday professional planning, and more part of public consciousness in dealing with social issues. For example, with the revolutionary new availability of personal computers and the widespread availability of software programs, it is not unusual to see high school students routinely performing the kind of regression analysis that a decade or so ago might have qualified someone for a Master's Degree. Similarly, we can expect to find other techniques and theories of forecasting finding their way into classroom curricula as part of the basic education of the coming generation. Perhaps for the first time in history, people will not be able to understand their own world without seeing the future it is being driven toward. An increasingly large component of our social system is devoted to the creation of things that are beyond our present experience. Future studies are no longer a spectator sport, carried out by an elite group of professionals in think tanks, while everyone else waits for the answers. Forecasting is becoming more accessible, more permeative, more democratic. As a consequence, it is becoming more politicized, more the focus of critical debate, more discerning about options, more part of our culture.

V. A Final Observation

It is often pointed out that techniques of social science can only be as good as their user. This is particularly true of forecasting, a field whose ground rules are still being written. The validity and fruitfulness of forecasting depends on checks and balances between the tendencies toward

rigorous but narrow-minded techniques on the one hand, and the imaginative but sometimes careless speculation about alternative future on the other. Coming back to a point made at the beginning of this paper, the dialectic between quantitative and qualitative methodologies is one way to help sustain both rigor and imagination in forecasting, while counteracting the inherent weakness of each of those two approaches. Among all the methodological considerations of forecasting applied to educational planning, this integration of quantitative rigor and qualitative sensitivity seems the most difficult and yet the most important task before us.

Footnotes

1. The Appolonian approach to science is oriented toward analysis (breaking down of wholes in parts, attention to details), while the Dionysian looks for synthesis (the search for essences, unifying principles, organic wholes). This duality can be traced back to ancient Greece. More recently (with Galileo, William Harvey and Kant), another form of scientific dialectic became more pronounced - the complementary use of data and theory, or inductive-empirical and deductive-theoretical ways of thinking (see Conant, 1965).

2. "Right-brain" thinking is described as intuitive, visual, pattern-seeking, wholistic, aesthetic, creative; "left-brained" thinking operates with more fixed, logical and unemotional building blocks of words and numbers considered in sequence (Ornstein, 1974). Social science traditions give primacy to verbal and mathematical skills, while neglecting "right brain" capacities that probably also have important applications, particularly in the field of educational forecasting. The left/right division is based on recent brain research showing that these mental functions tend to be located in separate halves of the brain. There is evidence that individuals have varying capacities to synthesize the two approaches in problem-solving; that this ability can be learned; and that most systems of education (including professional training programs) do a poor job in realizing this potential.

3. Related to the distinction between the "science of discovery"and "science of justification" (Reichenkach, 1938), one can also cite Thomas Kuhn's "normal science" and "extraordinary science" (Kuhn, 1970); Holton's "science-in-the-making" (speculative, creative, individualistic, unorthodox, seasonal)

and "public science" or "science-as-an-institution" (evolving compromises on truth, based on systematic testing and detailing of accepted premises). (Holton, 1952, pp. 236-45; Holton, 1975, pp. 328-329). Forecasting, more than most other social sciences, brings the speculative and rigorous sides of science together in the investigation of realities that are still evolving.

References

Adelson, Marvin (1967) "The Educational Innovation Study," American Behavioral Scientist 10:7 (March), pp. 8-12.

Ayres, Robert U. (1969) Technological Forecasting and Long-Range Planning, McGraw-Hill.

Barclay, George W. (1958) Techniques of Population Analysis, New York: John Wiley & Sons.

Bateson, G. (1976) "Breaking Out of the Double Bind," Psychology Today, 12 (August), pp. 43-51.

Beck, R. H. (1974) "Values and Forecasts," in Hencley & Yates (eds.) Techniques of Educational Forecasting. Berkeley, Calif.: McCutchan.

Blackburn, Thomas R. (1971) "Sensuous-Intellectual Complementarity in Science," Science 172 (4 June), pp. 1004-1007.

Boskin, M. J., & Nold, F. C. (1975) "A Markov Model of Turnover in Aid to Families With Dependent Children," Journal of Human Resources 10, pp. 466-481.

Brown, D. J. (1972) Organizational Mobility of Educational Administrators, unpublished Doctoral Dissertation, Graduate School of Education, University of Chicago.

Brown, D. J. (1974) "Educational Trend Analysis Methods," in Hencley & Yates (eds.) Techniques of Educational Forecasting. Berkeley, Calif.: McCutchan.

Bruno, J. E. (1970) "Use of Monte Carlo Analysis to Determine Optimal Size of Substitute Teacher Pools," Journal of Socio-Economic Planning Sciences 4, pp. 415-425.

Bruno, J. E. and Marcus, M. (1971) "Use of Leontief Analysis in Determining Indirect Costs," Journal of Socio Economic Planning Sciences 5(4), pp. 285-294.

Bruno, J. E. (1975) "A Comparison of Methods for Long-range Assessment in Education," Journal of Socio Economic Planning Sciences 9, pp. 293-299.

Bruno, J. E. & Nelkin, I. (1975) "Propensity of Teachers to Strike," Education Administration Quarterly, 11:2, pp. 66-86.

Bruno, J. E. (1974) "Monte Carlo Techniques in Educational Forecasting," in Hencley & Yates (eds.) Techniques of Educational Forecasting. Berkeley, Calif.: McCutchan Publishing Corporation, pp. 347-372.

Bruno, J. E. (1976) Educational Policy Analysis, New York: Crane Russak.

Bruno, J. E. & Shuford, E. (1978) "Individual Assessment of Knowledge From Standardized Test Scores," Manuscript (to be published in 1979 in Education and Psychology Measurement).

Cetron, M. J., & Monahan, T. I. (1968) "An Evaluation and Appraisal of Various Approaches to Technological Forecasting," pp. 147ff in J. R. Bright (ed.) Technological Forecasting for Industry and Government. Englewood Cliffs: N.J.: Prentice-Hall, Inc.

Charters, W. W., Jr. (1970) "Some Factors Affecting Teacher Survival in a School District," American Educational Research Journal 7:1 (Fall), pp. 1-27.

Clark, I. F. (1969) "A Brief History of Technological Forecasting," pp. 149-155 in R. V. Arnfield (ed.) Technological Forecasting. Edinburgh: University Press.

Coleman, J. (1966) The Equality of Educational Opportunity. Washington, D.C.: U. S. Government Printing Office.

Conant, James B. (1965) Two Modes of Thought. New York: Bantam Books.

Correa, H. (1975) Analytical Models in Educational Planning and Administration. David McKay.

Davis, Russell G. (1966) Planning Human Resources Development: Educational Models and Schemata. Chicago: Rand McNally.

Doscher, L. (1978) "Reliability of Standardized Testing Procedures," unpublished Doctoral Dissertation proposal, Graduate School of Education, University of California, Los Angeles.

Duff, W. and Lynch, R. (1976) "Graduate Admission Policy: A Bayesian Analysis, Journal of Experimental Ed. 45 (Spring), pp. 38-41.

Emmerij, L. J. (1965) "Planning Models for the Calculation of Educational Requirements for Economic Development--Spain," Part II in J. Tinbergin & H. C. Bos, Econometric Models of Education. Paris: OECD.

Encel, Solomon, Marstrand, Pauline K. and Page, William (1976) The Art of Anticipation: Values and Methods in Forecasting. Pica Press.

Evanco, W. (1976) "Multinomial Logistic Enrollment Models: Application to Iraqi Primary Education," Educational Planning 3:2 (October), pp. 53-65.

Ferguson, T. L. (1976) An Analytical Perspective for Examining School District Policies for Classification of Students to Special Education. Unpublished master's thesis, School of Education, California State University, Los Angeles.

Filstead, William J., Ed. (1970) Qualitative Methodology: Firshand Involvement With the Social World. Chicago: Markham Publishing Company.

Frankel, M. M. & Harrison, F. W. (Eds.) (1977) Projections of Educational Statistics to 1985-86. Washington, D.C.: Department of HEW, U. S. Government Printing Office.

Gold, B. K. (1966) Quantitative Methods for Administrative Decision Making in Junior Colleges. Unpublished Doctoral Dissertation, Graduate School of Education, University of California, Los Angeles.

Goodman, Paul and Goodman, Percival (1960) Communitas. 2nd Ed. New York: Vintage Books.

Gordon, Theodore J. (1972) "Current Methods of Futures Research," pp. 164-189 in Alvin Toffler, The Futurists. New York: Random House.

Gordon, T. J. & Hayward H. (1968) "Initial Experiments with Cross Impact Matrix Method of Forecasting," Futures 1:2 (December), pp. 100-116.

Green, P. E., & Rao, V. R. (1971) "Conjoint Measurement for Quantifying Judgmental Data," Journal of Marketing Research 8 (August), pp. 355-363.

Guffan, M., and Schmitt, J. (1966) "A Monte Carlo Model for the Prediction of Public School Enrollments," Paper presented at the meeting of the American Educational Research Association, Minneapolis, Minnesota.

Hencley, S. P. and Yates, J. R. (eds.) (1974) Futurism in Education. Berkeley, Calif.: McCutchan Publishing Corporation.

Holton, Gerald (1952) Introduction to Concepts and Theories in Physical Science Reading, Mass.: Addison-Wesley Publishing Company.

Holton, Gerald (1975) "On the Role of Themata in Scientific Thought," Science 188:4186 (25 April), pp. 328-34.

Horowitz, Ira (1970) Decision Making and the Theory of the Firm, Chicago: Holt, Rinehart and Winston, Inc.

Hudson, Barclay (1973) "The University as Social Intervention Agent." Los Angeles: UCLA Urban Planning Program, Mimeo.

Hudson, Barclay M. (1977) "Educational Planning: Notes on the State of the Art," Los Angeles: UCLA Urban Planning Program. Working Paper DP-104.

Hudson, Barclay M. (1978) "Forecasting Educational Futures. Resolving Uncertainties and Disagreements Through Compact Policy Assessment." Paper prepared for the World Future Society/University of Houston Conference on Educational Futures, Clear Lake, Texas, 20-22 October 1978.

Hudspeth, D. (1974) "The Cross Impact Matrix," pp. 115-126 in S. P. Hencley and J. R. Yates (eds.) Futurism in Education. Berkeley, Calif.: McCutchan Publishing Corporation.

James, William (1925) Pragmatism. A New Name for Some Old Ways of Thinking. New York: Longmans, Green and Company. (Orig. pub. 1907.)

Jantsch, Erich (1966) Technological Forecasting in Perspective. Paris: Organization for Economic Cooperation and Development.

Johnstone, J. N. and Philip, H. (1973) "The Application of a Markov Chain in Educational Planning," Journal of Socio-Economic Planning Sciences, 7:3, pp. 283-294.

Kerr, Clark (1964) The Uses of the University. Cambridge, Mass.: Harvard University Press.

Klein, S. and Alkin, M. (1971) Program, Planning Tools and Procedures Evaluation Workshop. Proceedings of a Conference held at Monterey, California. McGraw-Hill.

Kuhn, Thomas S. (1970) The Structure of Scientific Revolutions. 2nd edition. Chicago: University of Chicago Press.

Lanford, H. W. (1972) Technological Forecasting Methodologies. New York: American Management Association, Inc.

Legare, J. (1972) "Methods of Measuring School Performance Through Cohort Analysis," Demography, 9:4, pp. 617-625.

Leontief, W. (1951) Structure of the American Economy. New York: Oxford University Press.

Linstone, Harold A. and Turoff, Murray, Eds. (1975) The Delphi Method. Techniques and Applications. Reading, Mass.: Addison-Wesley Publishing Company.

Lovell, C. C. (1971) Student Flow Models: A Review and Conceptualization. Boulder, Colo.: National Center for Higher Education Management Systems at Western Interstate Commission for Higher Education.

McCall, John and Wallace, Nell (1967) Training and Retention of Air Force Airmen (RM-5384). Santa Monica, Calif.: Rand Corporation.

McFarland, D. (1970) "Intragenerational Social Mobility as a Markov Process," American Sociological Review, 35 (June), pp. 463-475.

McNamara, J. F. (1970) The Efficient Allocation of Vocational Technical Education Funds. Harrisburg, Pennsylvania: Pennsylvania Department of Education.

McNamara, J. F. (1974) "Markov Chain Theory and Technological Forecasting," pp. 301-345 in S. P. Hencley and J. R. Yates (eds.) Futurism in Education. Berkeley, Calif.: McCutchan Publishing Corporation.

Mandanis, G. P. (1969) "The Future of the Delphi Technique," pp. 159ff in R. V. Arnfield (ed.), Technological Forecasting. Edinburgh: University Press.

Martino, J. P. (1973) "Technological Forecasting for Planning Research and Development," pp. 106-125 in J. R. Bright and M. S. F. Schoeman (eds.) A Guide to Practical Technological Forecasting. Englewood Cliffs, N. J.: Prentice-Hall, Inc.

Meadows, D. L. and others (1971) The Limits to Growth. Patomic Associates for the Club of Rome.

Mesarovic, Mihajlo and Pestel, Edward (1974) Mankind at the Turning Point. E. P. Dutton & Company.

Mohrenweiser, G. (1969) A Markov Chain Model for Projecting School Enrollments. Unpublished Doctoral Dissertation, Graduate School of Education, University of Minnesota.

Morgan, B. W. (1968) An Introduction to Bayesian Statistical Decision Processes Englewood Cliffs, N.J. Prentice-Hall.

Meyer, D. and Collier, R. (1970) Bayesian Statistics. F. E. Peacock Publishers Inc.

Nafziger, D. M. (1973) "A Markov Chain Analysis of the Movement of Young Men Using the Holland Occupational Classification (Report #48)." Baltimore, Maryland: Center for Social Organization of Schools, John Hopkins Universi

Nordell, L. P. (1967) A Dynamic Input-Output Model of the California Educationa Systems (TR #25). Berkeley, Calif.: Center for Research in Management Science, University of California

Ornstein, Robert E. (1974) The Nature of Human Consciousness. Viking Press.

Peseau, B. A. (1972) "The Nature of Technological Forecasting and Its Relationship to Long-Range Educational Planning," Education Planning, 2, pp. 2-7.

Reichenbach, Hans (1938) Experience and Prediction. Chicago: The University of Chicago Press.

Reiger, M. H. (1968) "A Two State Markov Model for Behavioral Change," Journal of the American Statistical Association, 63, pp. 993-999.

Reisman, A. and Taft, M. (1969) "The Generation of Doctorates and Their Feedback into Higher Education," Journal of Socio-Economic Planning Sciences, 2, pp. 473-486.

Smith, P. E. (1961) "Markov Chains, Exchange Matrices and Regional Development, Journal of Regional Science, Vol. 3, pp. 27-36.

Stanford Research Institute (1970) Alternative Futures and Educational Policy. Menlo Park, Calif.: SRI Educational Policy Research Center.

Tanner, C. K. (1972) "Futuristic Models for Educational Choice," Educational Planning, 2 (June), pp. 10-20.

Tinbeigen, J. and Bos, H. C. (1965) "Planning Model for the Educational Requirements of Economic Development," Part I of Econometric Models of Education. Paris: OECD.

Toffler, Alvin (1970) Future Shock. New York: Bantam Books.

Toffler, Alvin (1972) The Futurists. New York: Random House.

Unesco (1966) Estimating Future School Enrollment in Developing Countries, by Bangnee Alfred Liu. Paris: Unesco.

Vroom, V. H. and MacCummar, K. (1968) "Toward A Stochastic Model of Managerial Careers," Administrative Science Quarterly, 13 (June), pp. 26-46.

Weatherman, R. and Swensen, K. (1974) Pages 97-114 in Hencley and Yates (eds.) Futurism in Education, Berkeley, Calif.: McCutchan Company.

Williams, G. (1965) "Planning Models for the Calculation of Educational Requirements for Economic Development--Greece," Part IV in J. Tinbeigen and H. C. Bos (eds.), Econometric Models of Education. Paris: OECD, pp. 77-92.

Wind, Y. and Spitz, L. (1976) "Marketing Decisions in Health Care Organizations Operations Research 24:5 (September-October), pp. 973-990.

World Future Society (1977) Resources Directory for America's Third Century. Washington: WSF.

Yoda, K. (1972) "An Application of Markov Chains and a Monte Carlo Simulation to Decision Making Behavior of an Educational Administrator," Educational Planning, 2 (June), pp. 28-39.

Young, Michael (1968) Forecasting and the Social Sciences. London: Heinemann Educational Books Ltd.

Yuji, Ijiri and Simon, H. A. (1964) "Business Firm Growth and Size," American Economic Review, 54:2 (March), pp. 77-89.